ABSTRACT
        Evaluated were the properties and fine structures of
averaged visually evoked potentials (AVEP) in 60 normal children
between the ages of 2 and 9 years. Electroencephalographic recordings
were taken while white diffuse flashes were used to deliver visual
stimuli to the Ss. Three types of AVEP patterns were discerned, with
no relationship observed between AVEP types and age of Ss; however,
AVEP latencies of the third type appeared to be closely related to
age. Results implied that AVEP latency is related to age in early
developmental stages but becomes unrelated to age at later stages.
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RIEEC RESEARCH BULLETIN

RRB-3

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Tohru Mizutani

Shuji Izawa

and

Yoshiaki Mitani

March 1973

The Research Institute for the Education of Exceptional Children

Tokyo Gakugei University

Koganei, Tokyo, Japan

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Tohru Mizutani, Shuji Izawa and Yoshiaki Mitani

Research Institute for Education of Exceptional Children

Tokyo Gakugei University

The analysis of averaged visually evoked potential (AVEP) has already been performed by some workers (Ellingson; 1966 ; Ferriss et al., 1967 ; Creutzfeldt and Kuhnt, 1967 ; Umezaki and Morrell, 1970). Most of these works deal with the changes of peak latency or amplitude with increasing age in newborn infants. As for the AVEP pattern, Creutzfeldt and Kuhnt identified three types during infancy and childhood, and Umezaki and Morrell also differentiated three types of initial positive component of AVEPs in neonates. However, there are still unclear points in AVEP properties in childhood.

The purpose of the present study is to seek for the properties of AVEPs and their fine structures in normal children. We will introduce a part of the results on AVEP latencies obtained in our labolatory.

1. MATERIALS AND METHODS

Sixty normal children were used. Those were selected from 77 subjects examined, out of which 17 subjects were excluded because of EEG abnormalities, blurred vision, neurological disturbances such as convulsive disorders in

presence or history and mental retardation. Ages are ranging from 2 years 11 months to 8 years 10 months, and the range of IQ is 105 through 155 (mean IQ : 128).

Scalp electrodes were placed at C_3, O_1 and O_z chosen by the 10 - 20 international method, and at the left ear lobe (A_1) as reference. White. diffuse flashes were delivered to the subjects with 2 second intervals, after darkness adaptation during 10 minutes. The flash illuminance at the eyelids was 12000 lux, and the duration was 20 μsec. The lamp was settled in a container filled with fiber glass, so that no appreciable click-evoked potentials were expected.

The segments of data were amplified and recorded on the magnetic tape by using of ME-95C/R-400 system. Those segments modified by artifacts and/or drowsy conditions were excluded.

The averaging of single visually evoked potentials (SVEPs) was carried out by a digital averager ATAC-501-10, with digitizing rate of 1.6 msec. For most of all subjects 128 EEG segments were averaged, except 8 subjects for whom 64 segments were averaged. The averaged digitized results were then converted again into analogue signals and plotted by a X-Y plotter XYR-2A. Furthermore, the digitized AVEPs obtained were also punched out on 8 bit paper tape for further computer processings.

2.   CLASSIFICATION OF AVEP PATTERNS

The AVEPs were observed generally within 400 msec after the flash ;

- 2 -

those processes are a little longer than those obtained in adults (within 250 msec; see Cigánek, 1961; Kooi and Bagchi, 1964) and shorter than those in neonates and early infants (within 500 msec; see Ferriss et al.,1967; Umezaki and Morrell, 1970).

In those AVEPs, four peak components were differentiated : the initial component is the negative peak (N_1, 70-110 msec in latency), and it is followed by the positive (P_1, 100-200 msec), negative (N_2, 200-300 msec) and positive (P_2, 250-400 msec) components. The sets of these four components constitute the four different types of AVEP patterns, namely, Types A, B, C and D. The typical samples of such four types of AVEPs are shown in Figure 1.

The Type A is specified by deep P_1 and following prominent N_2; AVEPs of this type account for 51.7 per cent of all observed at O_1 and as much as 58.3 per cent at O_z, whereas simply 3.3 per cent at C_3. In contrast to Type A, successive four small components are confirmed in a very small interval of time in Type B. Those types are observed at all regions (C_3 : 26.7 % ; O_1: 41.7 % ; O_z : 40.0 %). The Type C may be assumed a modified pattern of Type B; N_2 shows the prominent peak in addition to a short $N_1 - N_2$ which is observed at Type B. A large amount of the AVEPs at C_3 are classified to this type (60.0 %); contrary to this, the Type C is exceptionally observed at O_1 (3.3 %) and at O_z (1.7 %). The Type D will be summarized as the diphasic form with broad negative and positive deflection (N_1 and P_2), simply with the modifying small notches (P_1 and N_2). It occurred fractionally at O_1 and O_z, except at C_3 (10.0 %).

When we examine the regional difference of AVEP type within the individual child, the combination $C(C_3)$-$A(O_1)$-$A(O_2)$* is seen most frequently (28.3 %) and C-B-B is the next trend (23.3 %). Figure 2 shows a typical sample of C-A-A combination.

The results given in the second through fifth columns in Figure 1 are showing the averaging processes to reach those four types of AVEP patterns: the partial AVEPs which were obtained by averaging single responses to the first 16, 32, 64 and subsequent 64 flashes are arranged. Figure 2, as well, are added by the data of similar averaging processes. What is evident from these results is that the distinguishing features of the AVEP patterns,described at the beginning of this section,can practically be observed by averaging simply 16 or 32 responses. As might be suspected, the incidentally changed portions are found in the process of averaging,but they were not adopted in identifying the AVEP patterns. The detailed discussion on averaging will be restated in the later section.

One thing which should be noticed here, is that there is no relation observed between the differentiation of AVEP types and age at any region, at least within the limit of this investigation. With regard to the relation of AVEP to age, the most direct attack appears to be by analyzing the latencies of AVEP components, as will be described in the following section.

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* $C(C_3)$ denotes the Type C AVEP observed at C_3; and so on.

3. RELATIONS OF AVEP LATENCIES AND AGE

Due to the deep deflection of P_1 in Type A, it is expected that P_1, N_2 and P_2 should come out much later in Type A pattern as compared with those components in the other types. This is assured by Figure 3 showing the scatter diagrams representing the relations of latencies of AVEP components and age. The dots and crosses denote members of Types non-A and A respectively.

It is evident from Figure 3 that latencies of AVEP components in Type non-A tend to decrease in general with age; the relations are seen most clearly at C_3. To clarify those relations, the regression lines and the correlation coefficients were computed for Type non-A, and they are given in the diagrams. As compared with non-A, AVEP latencies in A reveal no confirmed relations to age, except N_1 which is taking the similar progress to that in Type non-A. Another thing to be seen for Type A is that P_2's at O_z are nearly 30 msec behind those at O_1. However, a clear solution to the cause has not been obtained.

The values of correlation coefficient between latencies and age for typical AVEP types at each region are given in Table 1A. The outline is as follows:

(1) $B(C_3)$ shows the strongest negative correlation in each component; subsequently, $C(C_3)$. This suggests that appreciable amount of relations observed at C_3 in Figure 3 were primarily due to Type B AVEPs.

(2) Among $B(C_3)$, $B(O_1)$ and $B(O_z)$, $B(C_3)$ alone exhibits the evident correlation to

- 5 -

age in any component, whereas no clear correlations were observed in $B(O_1)$ and $B(O_z)$.

(3)　　No noteworthy correlation values are recognized in Type A AVEPs; this is in agreement with the result seen in Figure 3.

Hence, it becomes clear that latencies of AVEPs observed at C_3 are closely related to age, whereas fractionally at O_1 and O_z.　　The meager correlations obtained at the occipital region agree approximately with such data as those by Ferriss and others (1967) and Umezaki and Morrell (1970), where they confirmed that AVEP latencies did not change after certain period of time (100 days after birth, Ferriss et al.).　　However, the regional difference of amount of correlation is not known in detail.　　Further investigation seems to be necessary to explain the mechanism.

4.　RELATIONS AMONG LATENCIES OF AVEP COMPONENTS

Table 1B shows the result of correlational analysis applied to the relations among latencies of AVEP components.　　The values of each cell denote the correlation coefficient and partial correlation coefficient, where age is partialed out, calculated for each AVEP type observed at each region.　　As might be suggested from Table 1A, age must be affecting, as a confounding variable, the inter-components correlation drawn by using samples varying in age.　　Hence, the partial correlation values should be necessary for discussing the relations among components.

What is evident from Table 1B that two negative components N_1 and N_2 are

not correlated for any type of AVEP observed at O_1 and O_z. It may suggest that N_1 and N_2 are relatively independent processes on a physiological point. Further, comparing Type A with B at O_z, the partial correlation in A between two successive components P_1 and N_2 is fractional, whereas appreciable for N_1-P_1; this is opposed to the property of Type B. This suggests that P_1 in A, despite its deep deflection, is closely related to the preceding N_1, and in contrary with this, P_1 in B would rather be relevant to the following N_2. The similar trend is indicated for Types A and B at O_1, provided that P_1 in A proves to be related to N_2 as well as N_1.

When we proceed to compare B (C_3) with $B(O_1)$ and $B(O_z)$, $B(C_3)$ gives a set of appreciable partial correlation values among N_1, P_1 and N_2, which is different from the set of values in $B(O_1)$ or $B(O_z)$ suggesting the split of N_1 and P_1-N_2. Therefore, it may be assumed that $B(C_3)$ is dissimilar in property to $B(O_1)$ and $B(O_z)$ for all their similarity in pattern. Finally, the Type C is seem to agree approximately with $B(O_1)$ or $B(O_z)$ rather than $B(C_3)$ in property. It is estimated to consist of two independent negative components N_1 and N_2 (N_2 is associated by P_1).

Thus, it was demonstrated that AVEPs of three types A, B and C comprise the two uncorrelated components N_1 and N_2, except $B(C_3)$ which has closely connected N_1-P_1-N_2. However, it is also true from Table 1A that the distinguished relation of AVEP latency to age is found to be limited to $B(C_3)$, hence, we may assume that the segregation of N_2 from N_1 is affecting the reduction of correlation between AVEP and age. Further, assuming that AVEP latency

gets unrelated to age by maturation (see Umezaki and Morrell, 1970), $B(C_3)$ may be estimated to be still at an incomplete stage to reach segregation of N_2, and consequently be related to age.

5. DISCUSSION

It should be noted that the AVEPs analyzed in this study were restricted to the patterns appeared within 400 msec after the stimulus. The background activities were suppressed at least within this period of time, hence, the averaging was expected to give the signal-to-noise enhancement for obtaining the AVEPs. However, the problem lies in excluding the discussion on what is called "rhythmic after-discharge" of AVEP beginning from 240 msec after stimulation (see Cigár..k, 1961). In this respect, Figures 1 and 2 give that those waves cannot be entirely neglected, only they are inconsistent in the process of averaging.

Barlow has presented evidence that although the frequency of the after-discharge is generally close to the predominant frequency of the alpha activity, nevertheless the after-discharge cannot entirely be explained as an instrumental sampling artifact. Although Brazier has shown that some dissociation between the after-discharge and alpha activity can be achieved by the use of pharmacological agents, there is wide agreement that the two phenomena are closely related. However, by subtracting spontaneous activity from EEG samples recorded after stimulation, Magnus and Ponson obtained results which, they claimed, showed that the after-discharge was little affected by the phase of the alpha cycle at

- 8 -

which stimulation took place.   On the other hand, Peacock (1970) has suggested

that the after-discharge should be regarded as the averaged development of aipha

regeneration following flash-induced blocking.   It may be suggested that a part of

our future subjects lies in clarifying those processes in childhood.

Another thing to be discussed will be the assumption drawn by the result

in the preceding section.   We suggested that $B(C_3)$ still remained at an

incomplete stage to reach the segregation of N_2, and this caused showing relation

of AVEP latency to age.   Umezaki and Morrell (1970) observed that the second

positive peak, as they denoted, gradually became dominant to the first negative

peak to attain the matured AVEP, where no further decreasing of latency correlated

to age was expected.   The similar result was obtained by Ferriss et al. (1967).

These results appear to be the proofs of our assumption.   However, there are

still uncertain points; further experiments should be made to explain the mecha-

nism underlying.

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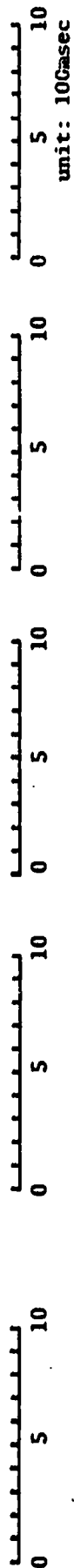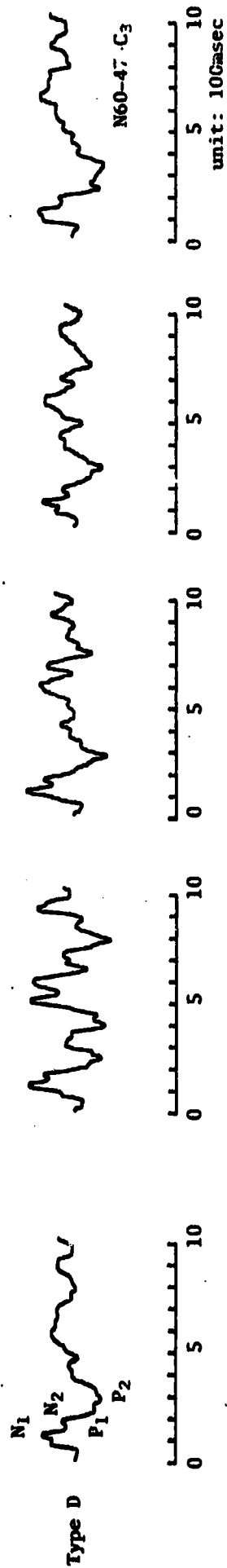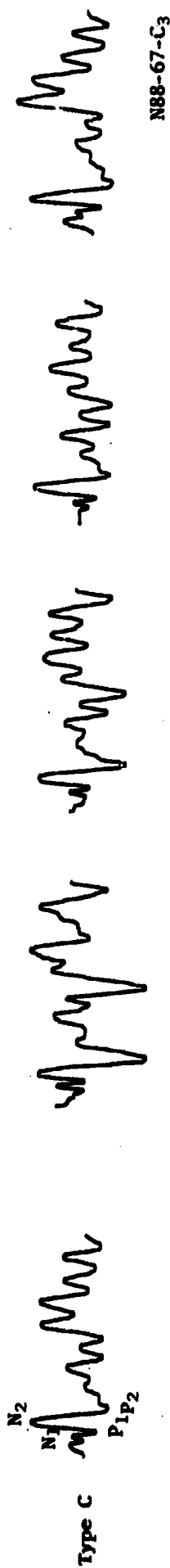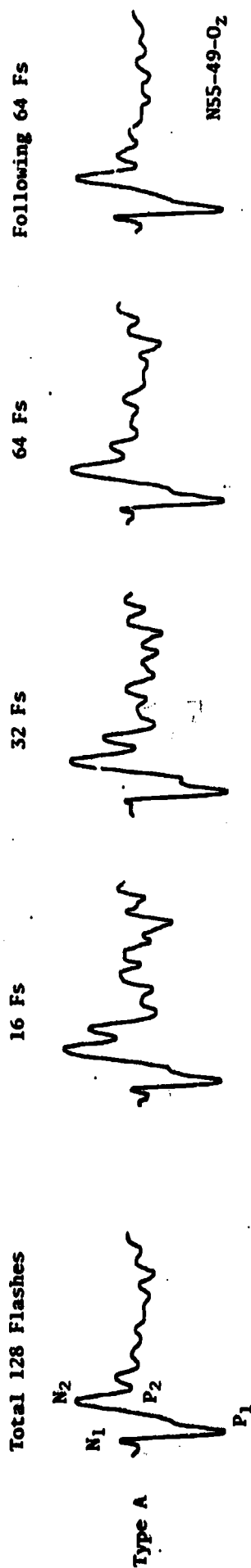
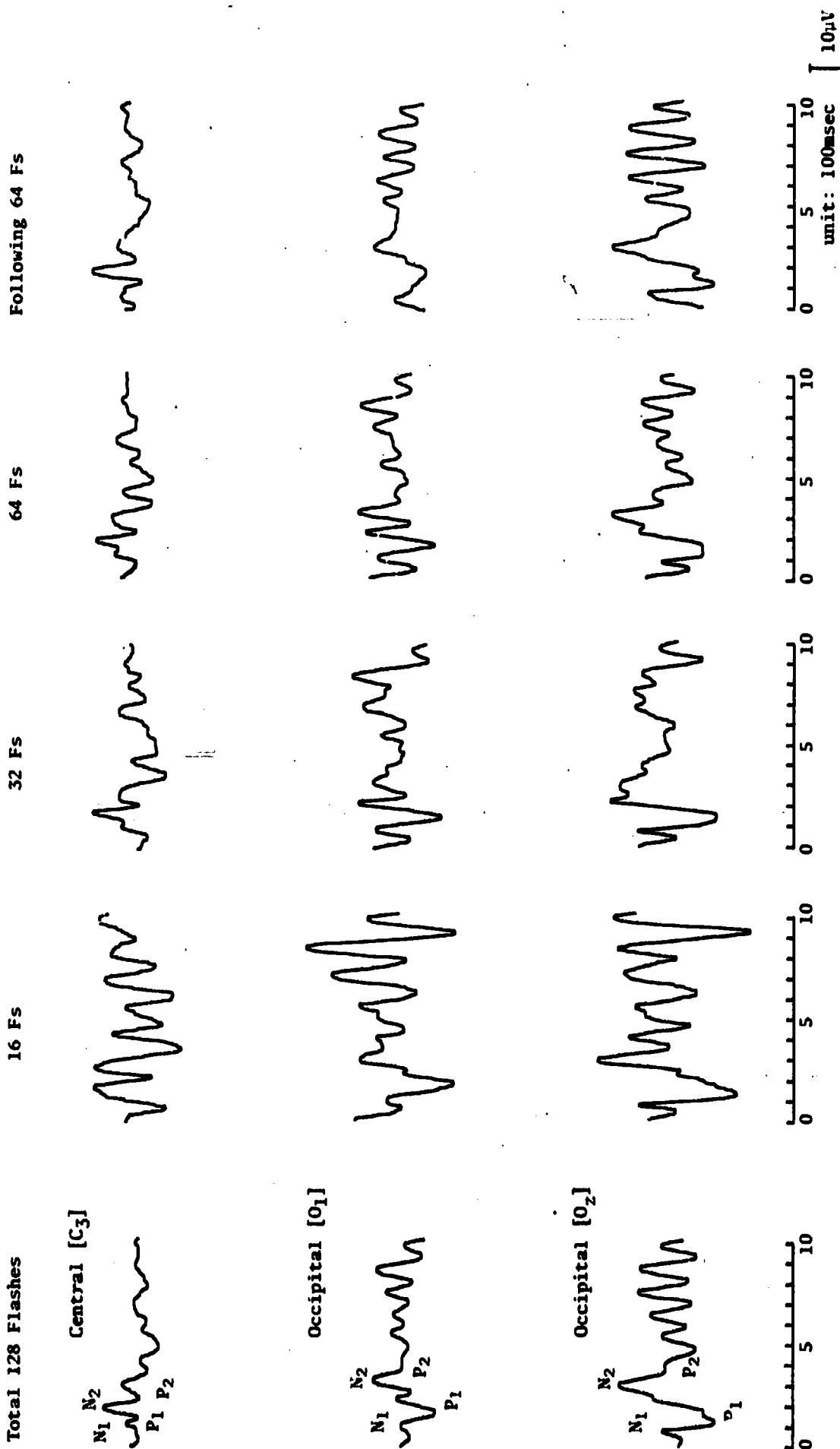Figure 1. Four types of AVEPs in normal children and their averaging processes
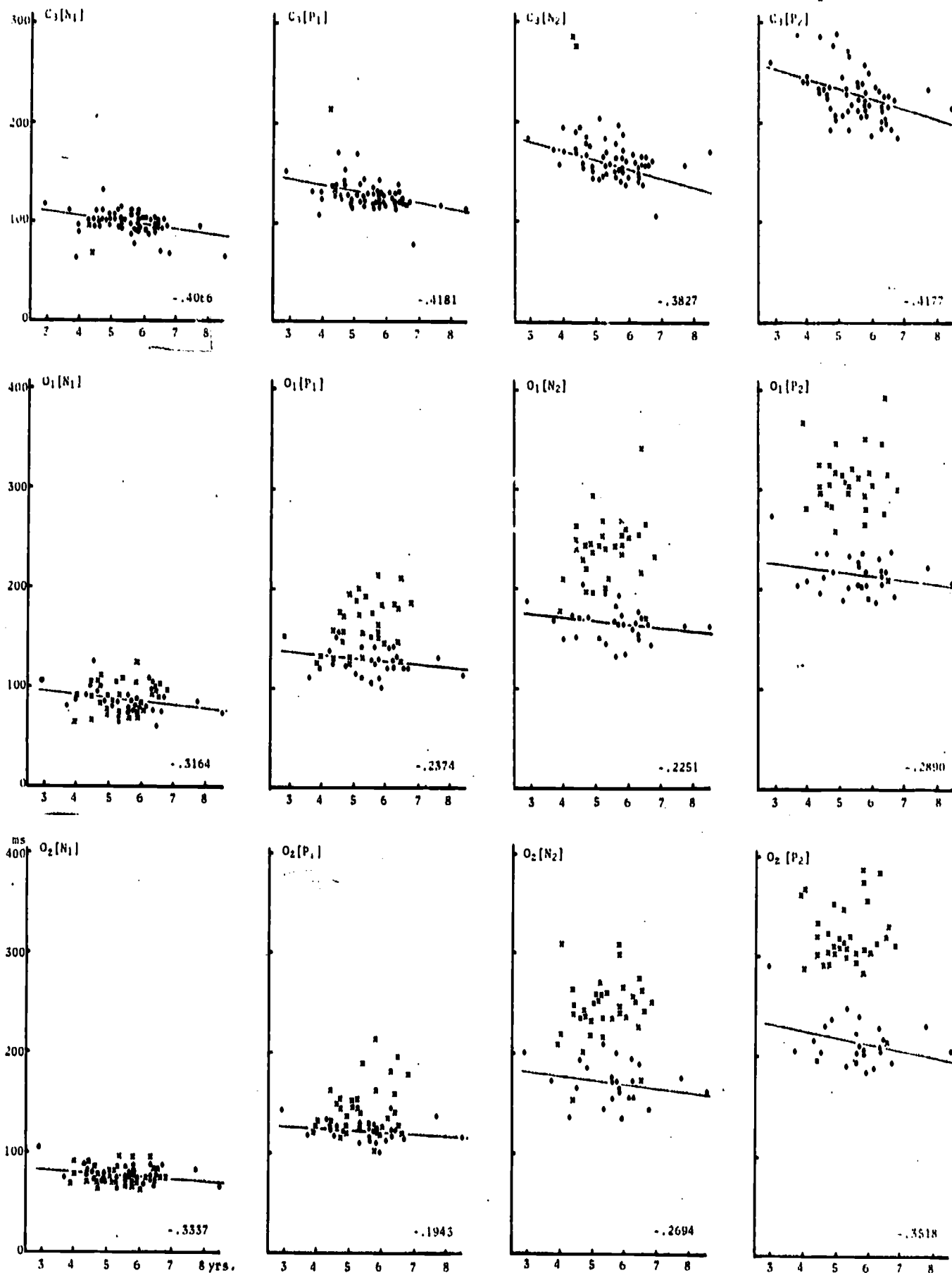
Figure 2. AVEPs differing in shape and property due to recording areas

Figure 3. Scatter diagrams representing relations
of AVEP latencies and ages

Table 1A.
Correlation coefficients between latencies of AVEP components
and age for six groups when AVEPs are classified
in terms of types and regions

region	type	samples	N_1	P_1	N_2	P_2
C_3	C	N=36	-.3726	-.3295	-.2727	-.4626
	B	N=16	-.5465	-.5345	-.6751	-.5204
O_1	B	N=25	-.3270	-.1959	-.2165	-.3030
	A	N=31	.1670	.3361	.2466	-.0909
O_z	B	N=24	-.0716	.0099	-.1375	-.0601
	A	N=35	.0123	.2785	.0820	-.0735

Table 1B.
Correlation and partial correlation coefficients
among latencies of AVEP components

region	type	N_1-P_1	N_1-N_2	N_1-P_2	P_1-N_2	P_1-P_2	N_2-P_2
C_3	C	.6135	.3230	.3223	.8217	.4554	.4962 [1]
		.5602	.2479	.1823	.8057	.3619	.4339
	B	.8562	.6690	.4025	.8294	.4531	.7097
		.7969	.4857	.1652	.7515	.2424	.5688
O_1	B	.4503	.1104	.3046	.8266	.7305	.7572
		.4168	.0430	.2282	.8191	.7182	.7435
	A	.5577	.3012	.0914	.6456	.4053	.6010
		.5401	.2722	.1084	.6166	.4646	.6460
O_z	B	.4103	-.1065	-.0900	.5999	.5463	.9152
		.4120	-.1177	-.0947	.6069	.5478	.9173
	A	.6826	-.0030	-.0449	.0192	-.1494	.6231
		.7072	-.0040	-.0441	.0182	-.1346	.6329

1] Lower value of each cell denotes partial correlation
coefficient when age is partialed out.